

Water for Energy

A critical piece of the energy sustainability puzzle

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Few people need to be convinced that national security and the standard of living enjoyed in the United States depend on an abundant, reliable, and sustainable supply of electricity. Likewise, no one doubts the importance of clean and abundant water to our economy, health, and the environment. However, insufficient attention has been paid to the intimate connection between energy and water. Vast amounts of water are needed to support electricity production. Could future water shortages be an overlooked vulnerability that hinders our attempts to achieve national energy security and sustainability? And if so, what scientific and technical steps could be taken to address the problem?

Thermoelectric power production, which includes coal-fired and nuclear power plants, is second only to agricultural irrigation in fresh water withdrawals. As shown in Figure 1, irrigation and thermoelectric power generation are nearly tied in the amount of fresh water withdrawn annually (Solley et al. 1998): 134 billion gallons per day (Bgal/day) and 132 Bgal/day, respectively. Of the 132 Bgal/day withdrawn by power generation, 71 percent supports electricity generation from fossil fuels, and 29 percent supports electricity generation from nuclear power plants. These numbers reflect only the amount of cooling water withdrawn for condensing steam in steam-electric power generation. They do not include water used in any other phase of the energy cycle—such as fuel mining, refining, or

transport—nor do they include the enormous quantities of water that pass through hydroelectric plants.

The 132 Bgal/day seems alarmingly high until one accounts for the difference between withdrawal and consumption. Withdrawal is defined as the total amount of water extracted from a surface or groundwater body, whereas consumption represents the portion of withdrawal that evaporates, transpires, or becomes part of a product or crop. Irrigation and electricity generation are nearly equal in withdrawals, but irrigation consumes 81 Bgal/day, whereas power generation consumes only 3 Bgal/day.

Even though the quantity consumed in power production appears less troubling, 3 Bgal/day is not a trivial amount, and furthermore, the total amount must be available initially for U.S. power plants to continue operating as they do now. In addition, the 129 billion gallons that is returned to the source is typically 12°–30° Fahrenheit higher than the source body of water. Because the elevated temperature can harm aquatic organisms and alter the local ecosystem, strict thermal discharge limits and fish protection regulations have been imposed on power plants. Most plants already operate at the threshold of these limits. If water levels should drop, the heated discharge would raise the overall water temperature of the partially depleted lake or river beyond regulatory limits. The electric-power industry could find itself unable to keep up with electricity demand.

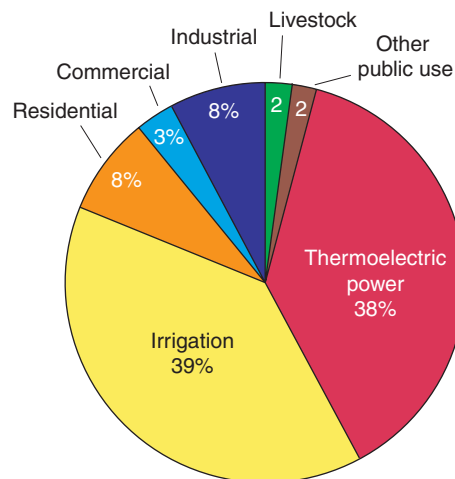


Figure 1. Water Withdrawals
This pie chart shows U.S. fresh water withdrawals in 1995 by sector. Thermoelectric power requires nearly as much water as agriculture.

An increase in the use of renewables would greatly alleviate the reliance of electricity on water, but renewables currently account for only 2 percent of U.S. electricity whereas coal and nuclear provide 72 percent. It is unlikely that any alternative can rapidly usurp 72 percent of the current electricity infrastructure and market. In fact, coal use is projected to increase steadily over the next 20 years while nuclear generation continues at its current capacity (U.S. Department of Energy 2003). As a result, water will remain critical to meeting energy demands.

Addressing the Problem

In searching for ways to address the issue of water for energy, we looked inward to a multidisciplinary group of scientists here, at Los Alamos National Laboratory, and outward to other national laboratories, the Electric Power Research Institute, industry representatives, and state water regulators. Based on our discussions, we believe a comprehensive solution should include the following three areas: (1) prediction and decision support, which would focus on creating a suite of decision tools that would help to identify trouble spots by analyzing “what if” scenarios, (2) tech-

nological solutions, which should focus on minimizing the effects of energy production on fresh water quantity and quality, and in particular, on investigating alternative cooling technologies, and (3) a concerted public/private partnership, because it is unlikely that the accelerated technology development and implementation suggested before will occur without it.

Decision tools would be based on coupled, high-performance computer models that link together the many complex systems and forces. (One such model is discussed in the article, "Virtual Watershed" on page 232.) The computational tools would help decision makers optimize the balance of water usage among stakeholders, guide technology investments, and aid economic development plans. The ultimate solution for thermoelectric power plants is condensing steam with a dry, air-cooled system, and such systems are already operating at a small percentage of U.S. plants. Although these systems can eliminate cooling water use by 95 percent, they are significantly more expensive to construct than wet systems and require four to six times the energy to operate. They are also much larger, taller, and louder than conventional systems, which may be of concern at certain locations (Electric Power Research Institute 2002a). Further development is necessary to decrease the cost and increase the efficiency of dry cooling systems.

Advanced drilling and pumping technology could help us access non-potable water from currently unused saline aquifers since thermoelectric power production does not require fresh water. Advanced sensing, filtration, and remediation are important as well because a large supply of contaminated water is the same as, or worse than, no water at all. By monitoring water conditions accurately and treating contamination rapidly and effectively, we can ensure that water resources remain usable and reusable.

It is also imperative that we accelerate the development and implementation of energy production methods that use less water or no water, including renewables such as solar and wind power. Hydrogen-powered fuel cells, for centralized and distributed power generation, hold great promise in the long term. They require only a small amount of water for fuel processing and no cooling water. They actually create water that can be recycled to the fuel-processing stage. The result is a net water consumption of approximately 30 gallons for every megawatt-hour (MWh) generated as opposed to the 300 and 400 gal/MWh consumed by coal-fired and nuclear plants respectively (Electric Power Research Institute 2002b). Los Alamos has been a leader in fuel-cell technology and will continue to develop robust and more efficient systems. (See the article, "Toward a Sustainable Energy Future" on page 240.)

Research and development focused on water for energy would involve long-term, high-risk investments with little near-term profit incentive, so it is unlikely that the private sector would pursue such a program aggressively. It is essential, therefore, that the federal government be involved. The complexity of the problem will require a multidisciplinary scientific and technical approach similar to the one typically employed at national laboratories.

Although the picture presented here is focused on the United States, the situation worldwide is very much the same and often worse. An increasing number of developing countries aspire toward the affluence of the United States and Western Europe, and that affluence correlates directly with the amount of energy consumed per person. As a result, global stability, which is crucial to our national security, will depend upon the same scientific and technological solutions required to achieve U.S. energy security and sustainability. Global stability will be dif-

ficult to achieve without a focused research and development effort to address the interdependencies between water and energy. ■

Further Reading

- Solley, W. B., R. R. Pierce, and H. A. Perlman. 1998. "Estimated Use of Water in the United States in 1995." U.S. Department of the Interior Geological Survey Circular 1200. Available on the Internet at <http://water.usgs.gov/watuse/pdf1995/html/>.
- U.S. Department of Energy. 2003. "Annual Energy Outlook 2003 Early Release." Energy Information Administration document AEI2003. Available on the Internet at <http://www.eia.doe.gov/oiaf/aeo/pdf/earlyrelease.pdf>.
- Electric Power Research Institute. 2002a. *Comparison of Alternate Cooling Technologies for California Power Plants: Economic, Environmental, and Other Tradeoffs*. Palo Alto, California: EPRI.
- Electric Power Research Institute. 2002b. *Water and Sustainability (Volume 3): U.S. Water Consumption for Power Production—The Next Half Century*. California Energy Commission document 1006786, Palo Alto, California.

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